



968 Albany-Shaker Road, Latham, New York

FOTONIC SENSOR

The MTI FOTONIC SENSOR is a non-contact instrument which measures linear displacement or motion by means of light rays. Any movement causes variations in the amount of light transmitted through a fiber optic probe and reflected by the work surface. This reflected light is conducted back through the probe to a photo receiver, whose output can be monitored by a panel meter, displayed on an expanded scale using an oscilloscope, or applied to an external recording device. The system is characterized by microinch sensitivity, high accuracy, the ability to make measurements in extreme environments, and a great diversity of possible applications. Unlike other non-contact systems, the FOTONIC SENSOR can operate with non-metallic or non-magnetic specimens, does not induce any disturbances of an electrostatic or electromagnetic nature, and is itself unaffected by such phenomena.

MODEL KD-45

The KD-45 is the "workhorse" of the FOTONIC SENSOR line. It can precisely measure static displacement, or the frequency and amplitude of displacement changes, over a variety of ranges determined by the fiber optic probe used. Its frequency response is from DC to 100 Kc, and it can resolve distance variations as small as 0.000010 inch (0.000001 inch with suitable filtering of its output). The standard probe used with the KD-45 is 0.109 inch in diameter and 36 inches long, and it extends from a separate cartridge containing the light source and the photocell. This cartridge can be connected directly to the instrument front panel or located remotely at the end of a 5-foot electrical cable. This feature allows use of fiber optic probes of sizes other than standard. Controls on the front panel permit adjusting the intensity of the light source, setting the "zero" of the built-in panel meter, and controlling the meter sensitivity without changing the instrument output. Provisions for operating from a 220 V power source can also be included on special order.



MODEL KD-36



The KD-36 employs two photocells and two amplifiers in a bridge circuit to obtain exceptional sensitivity over a displacement range of ± 0.001 inch. It is capable of resolving displacement variations of 0.000001 inch without external filtering, and it will produce a full scale (2.0 VDC) output for 0.000020 inch of movement if the surface under observation is highly reflective. To obtain this high sensitivity, the frequency response of the KD-36 is restricted and extends from DC to 20 cps. To maintain this sensitivity, the two photocells must be housed within the instrument case, so the 0.109 x 36 inch fiber optic probe extends directly from the front panel. The KD-36 front panel is also equipped with controls to permit adjusting the intensity of the light source, setting the "zero" of the built-in panel meter, controlling the instrument gain, and multiplying the instrument sensitivity by factors of two, four, eight, or sixteen. Calibration curves established for each instrument in the MTI laboratories are furnished for each of the five sensitivity ranges of the KD-36.

MODELS KD-38, KD-38A, AND KD-38B

The KD-38 is a low-cost, highly portable unit intended for measurement of displacement only. Its range is variable, depending on the fiber optic probe furnished (± 0.0025 inch with the standard 0.109 x 36 inch probe). Its frequency response is from DC to 60 Kc, and it can resolve displacement variations of 0.000015 inch. The built-in meter is factory—"zeroed", and a convenient calibration curve is supplied. A single control is provided to permit adjustment of the light source intensity. The fiber optic probe extends directly from the unit. The KD-38A is the same size as the KD-38 and shares its performance characteristics. However, its sensitivity is adjustable in three direct-reading steps of 0.5, 2.5, and 5 mils full scale, plus an approximate 25-mil full scale indirect reading position for which a calibration curve is furnished. Instrument gain and "zeroing" controls are also provided. The KD-38B is identical to the KD-38A except that additional amplifying, rectifying, and DC removal circuitry is incorporated to permit direct reading of vibration amplitudes.



KD-38B

PART OF A COMPLETE LINE
OF NON-CONTACT MEASURING EQUIPMENT

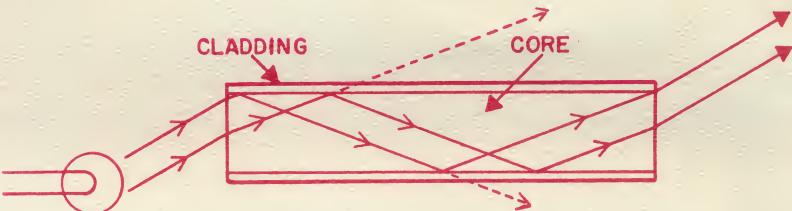
FIBER OPTICS

FROM



glass and synthetic

Optical fibers transmit light rays over long distances at high efficiency by multiple internal reflection. The fiber core is clad with a thin layer of lower refractive index material to enhance this effect and prevent optical crosstalk (caused by light rays transmitted to adjacent fibers along the paths shown by dotted lines in the figure at the right). The angle over which incident rays will be accepted for transmission through the fiber is controlled by selecting core and cladding materials with suitable indices of refraction.



GLASS FIBERS have been in use for several years. Fabrication technology is well established, and control of refractive index can easily be accomplished. Glass fibers are able to withstand temperatures as high as 1000°F.

SYNTHETIC FIBERS made from AST polymer have recently become available from MTI. They are almost indestructible and can be kinked, tied in knots, and bent through radii as little as 20 times their own diameter. A second cladding of opaque material can be provided on synthetic fibers when it is necessary to further reduce optical crosstalk. Synthetic fibers have excellent transmission characteristics, both in the visible spectrum and well into the infrared.

LIGHT GUIDES consist of bundles of non-coherent (randomly oriented) fibers bonded together at both ends but free to flex throughout the remainder of their length. MTI offers a comprehensive selection of such light guides as standard products, listed in the table below. These guides incorporate either glass or synthetic fibers, with individual fiber diameters ranging from 10 microns to 10 mils or larger. They are enclosed in protective sleeveings of polyvinyl chloride or neoprene, and stainless steel tips are fitted at each end. Light guides of non-standard length or incorporating larger or smaller fibers are available from MTI on special order.

Type	Nominal Bundle Diameter	Length (ft)	Model Number	
			Glass	Synthetic
A	1/16 in	1	A11612	NA11612
		2	A11624	NA11624
		3	A11636	NA11636
		4	A11648	NA11648
		5	A11660	NA11660
		6	A11672	NA11672
B	1/8 in	1	B12512	NB12512
		2	B12524	NB12524
		3	B12536	NB12536
		4	B12548	NB12548
		5	B12560	NB12560
		6	B12572	NB12572
C	3/16 in	1	C31612	NC31612
		2	C31624	NC31624
		3	C31636	NC31636
		4	C31648	NC31648
		5	C31660	NC31660
		6	C31672	NC31672
D	1/4 in	1	D25012	ND25012
		2	D25024	ND25024
		3	D25036	ND25036
		4	D25048	ND25048
		5	D25060	ND25060
		6	D25072	ND25072
E	3/8 in	1	E3812	NE3812
		2	E3824	NE3824
		3	E3836	NE3836
		4	E3848	NE3848
		5	E3860	NE3860
		6	E3872	NE3872

IMAGE GUIDES are similar to light guides but employ coherent fiber bundles (in which the relationship between fibers at one end is exactly duplicated at the other) to transmit actual images. Image guides for many different applications, as well as inspection equipment (e.g., borescopes) employing such guides, are available from MTI on special order.

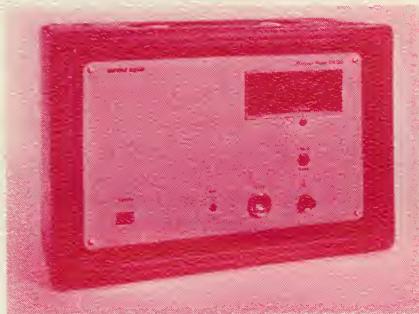
BRANCHED FIBER OPTIC BUNDLES can be provided in many different configurations. The distribution of the fibers at the common end of the bundle can be random, hemispheric, concentric, or arranged in other special patterns. Bifurcated bundles are used as the probes in the MTI line of FOTONIC SENSOR equipment and can also be supplied as individual items.

FIBER OPTIC ILLUMINATORS available from MTI are listed in the table below.

Type	Light Source	Accommodates Bundle Types	Features
Model 200 Illuminator	6.0V No. 1615 Lamp	A, B, & Large Single Fibers	Two-Position Intensity Switch
Model 400 Illuminator	115V DCL Lamp Blower Cooled	A, B, C, D, E	Variable Solid State Intensity Control
Chopper	115V DCL Lamp Blower Cooled	A, B, C, D, E	Modulated Light at 15, 30, 90, and 330 cps



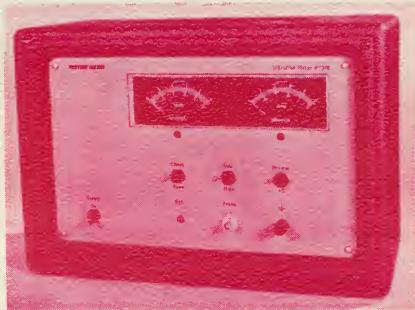
CAPACITIVE DISPLACEMENT INSTRUMENTATION



The DM-100 Distance Meter is designed to measure displacement using the capacitance probes described below, displaying the resulting measurement on a front panel meter. The resolution of the DM-100 depends on the probe used and can be as small as 0.0000001 inch. The instrument consists essentially of a high-gain amplifier, whose reference is supplied by an internal 50 Kc oscillator. The amplifier incorporates a negative feedback loop, which is completed by the capacitance between the probe tip and the object under observation. The amplifier output is displayed by an integrating DC VTVM, and this reading requires no interpretation or correction since it is an absolutely linear function of the probe-to-surface distance. Thus, the sensitivity of the DM-100 remains constant over the measurement range provided by the probe. Oscilloscope and recorder connections are furnished on the rear panel and can also be used for alarms, controls, or such functions as go/no-go sorting.

The B-731B Vibration Meter incorporates the same displacement measuring capabilities as the DM-100 Distance Meter and employs similar oscillator, amplifier, and feedback circuitry. In the B-731B, however, the output signal is also applied to a linear detector and a carrier filter which provides a cutoff beyond 10 Kc. The modulation wave obtained from the detector and filter is fed to a peak-to-peak voltmeter which indicates the vibration amplitude. Both the "averaged" (distance) and the "detected" (vibration) outputs of the B-731B are brought out to rear panel connections to permit recording or display. A special switch on the front panel provides an increase in the sensitivity of the vibration channel by a factor of five without altering the measurement accuracy. Neither the DM-100 Distance Meter nor the B-731B Vibration Meter is affected by the presence of a magnetic field near the probe. Both instruments operate satisfactorily in virtually any conventional industrial or field environment.

MADE FOR MTI BY THE WAYNE KERR LABORATORIES, LTD., Sycamore Grove, New Malden, Surrey, England



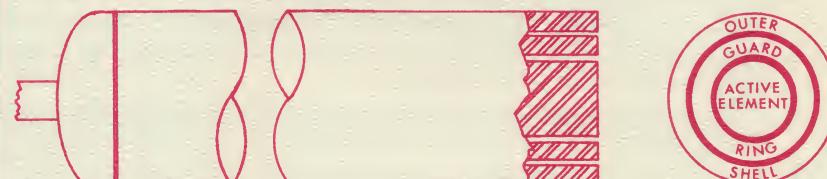
MICRO-DYNE CONSOLE ANALYSER

The MICRO-DYNE is a capacitive displacement system designed to monitor shaft vibrations under dynamic operating conditions using the capacitance probes listed at the right. A single console of the system will observe two motions 90° apart in a single plane and display them in an xy or displacement/time plot on an integral dual-beam oscilloscope. Several units can be combined to permit detailed study of movement in all three axes. Provision for switching from one console to another is included. System resolution depends on the probe used and can be as small as 0.0000001 inch. The frequency response, DC to 2 Kc, is linear over the operating range. The maximum drift rate is +0.05% per hr. A calibrated DC bias is provided. Modular construction is used in all critical areas of the system.

MADE FOR MTI BY
MILLIVAC INSTRUMENTS, INC., SCHENECTADY, NEW YORK

CAPACITANCE PROBES

The standard probes used with MTI capacitive displacement meters are circular, as illustrated below, and are available in the ranges listed in the table. The active element forms one plate of a capacitor, whose other plate is the conductive object under observation. The guard ring is maintained at the same potential as the active element to ensure that the field between the sensing tip and the test object remains uniform; it is isolated from ground by the outer shell. Rectangular probes and probes for particular applications are also available on special order.



Probe Range (mils)	Max. Temp. (°F)	Sensitivity (V/in.)	Repeatability (microin.)	Resolution (microin.)
0.1	240	10,000	0.2	0.1
1	100	1,000	2	1
1	400	1,000	2	1
5	400	200	10	5
10	400	100	20	10
10	1400	100	20	10
20	400	50	40	20
30	400	33.5	60	30
50	400	20	100	50
100	400	10	200	100

AUXILIARY PRODUCTS

FOR
USE
WITH



non-contact measuring equipment

MODEL KD-FO-1 DYNAMIC MEASUREMENT FILTER

In the measurement of dynamic phenomena with the MTI FOTONIC SENSOR and the MTI Capacitive Displacement Instrumentation, it has been found extremely helpful to improve the signal-to-noise ratio at the instrument output by removing both the high frequency noise from the instrument amplifier and the low frequency environmental noise transmitted through the probe and target mounting. The Model KD-FO-1 DYNAMIC MEASUREMENT FILTER has been designed to accomplish this function. Its use results in a significant reduction in the noise level presented to the display equipment. For example, the Model KD-45 FOTONIC SENSOR normally provides a resolution of 0.000010 inch with the standard 0.109 x 36 inch fiber optic probe. However, using the Model KD-FO-1 filter in conjunction with the KD-45 and the standard probe, MTI regularly makes dynamic measurements to a resolution of 0.000001 inch.

The Model KD-FO-1 DYNAMIC MEASUREMENT FILTER is essentially a band pass unit. Its high frequency response is down 3 db at about 150 Kc. At the low end, a four-position switch on the filter housing permits selection of a flat frequency response (OFF position) or a 3 db cutoff at either 32, 390, or 4500 cps.

MODEL FB-1 FILTER BALANCE UNIT

When a capacitive, inductive, or eddy current distance or vibration measuring instrument which employs a high frequency carrier signal is used in conjunction with an oscilloscope or a recorder, the high frequency component of the instrument output must be removed to prevent it from interfering with the displayed or recorded information. The Model FB-1 FILTER BALANCE UNIT has been designed to perform this function; it is capable of suppressing a 50 Kc carrier and its harmonics by at least a factor of 20.

The output of a capacitive, inductive, or eddy current vibration measuring instrument also contains a DC component which is a function of distance. This DC component often prevents use of high gain settings (for instance, when observing very small deviations) on display or recording equipment. An additional function of the Model FB-1 FILTER BALANCE UNIT is to generate a variable amount (0 to -1.3 VDC) of voltage to neutralize the positive DC component of the instrument output, so that the signal reference level can be varied at will and the signal, even when highly amplified, can be kept within the display or recording capabilities of the associated equipment.

FOTONIC SENSOR CARTRIDGES and the MODEL BX-1 POWER SUPPLY AND RELAY BOX

The FOTONIC SENSOR cartridge, containing a lamp and a photocell, is available as an individual item for use in long range measurement, tachometer pickup, or counting applications. It is capable of measuring displacements as great as one inch. For optimum results at large displacements, it must not be used without a light shield under conditions of high ambient illumination. The cartridge, either with or without a fiber optic probe, may also be used with the Model BX-1 POWER SUPPLY AND RELAY BOX for controlling, indicating, or slow counting. The trip point of the relay in the BX-1 is adjustable, but the supply is not regulated, so this instrument cannot be used for other than on/off applications.

REFRACTOSYN® SYSTEMS

Whenever it is necessary to measure extremely minute changes in angular displacement, the Model R29A REFRACTOSYN ELECTRONIC AUTOCOLLIMATOR provides an unequalled combination of simplicity, sensitivity, and low cost. With a 1.0 cps bandwidth and a stabilized environment, it can measure angles as small as 50 milliseconds of arc while exhibiting a null drift rate of less than 0.1 arcseconds per day. The REFRACTOSYN principle uses the unique Seward prism sensor, originally developed for space navigation, to achieve its extreme sensitivity. Other systems utilizing the REFRACTOSYN principle, including the Model 300-50 WIDEBAND ELECTRONIC AUTOCOLLIMATOR, the Model S-4 SUN SENSOR, and the Model TR-29A REFRACTOSYN ELECTRONIC THEODOLITE KIT, are available from MTI on special order.



CAN ALSO FURNISH ON SPECIAL ORDER THE FOLLOWING EQUIPMENT AND SERVICES:

- High frequency type capacitive and inductive non-contact displacement measuring equipment.
- A low cost strain gauge automatic sampling and recording system.
- Probe attachments for MTI non-contact measuring equipment to permit measurement of such variables as force, displacement, acceleration, velocity, magnetic and electrostatic field strength, high voltage isolated current, fluid turbidity, fluid flow, reflectance, temperature, fluid pressure, differential pressure, and angular motion.
- Fiber optic curve followers.
- Photoelectric controls.
- High reliability, extreme environment switching systems.
- Force measuring and transducing washers with high resolution which can withstand and accurately measure extreme shock.
- Branched fiber optic tape and card reading heads and systems.
- A controller and alarm module operating from the output of the standard FOTONIC SENSORS or other MTI non-contact measuring equipment.
- Ultra-high temperature strain gauges.
- Instrumentation for all high speed turbomachinery measurements, squeeze film bearing measurements, hydrodynamic and hydrostatic bearing measurements, and process fluid bearing and lubrication measurements.
- Application and design engineering for systems using glass and synthetic fiber optics.
- Machine signature analysis, reliability, and failure prediction.
- Reasonable cost, high quality, small item electromechanical assembly, test, and calibration.



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THE FOTONIC SENSOR

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INSTRUMENTS and CONTROL SYSTEMS

THE FOTONIC

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BY USING ADJACENT pairs of light sources and receivers, the distance to a reflecting surface can be measured by detecting the amount of reflected light (Fig. 1a). When sending and receiving elements are in contact with the surface, no light is reflected to the receiving element. As the distance between the elements and the surface increases, however, the cone of light from the transmitting element illuminates an increasingly larger area on the work surface. This area becomes, in effect, the source of a secondary cone of reflected light, which in turn increasingly illuminates the receiving element.

The relationship between surface displacement and receiver illumination remains essentially linear (Fig. 1b), until the entire surface of the receiving element is illuminated by the reflected light cone, at which point the curve reaches its peak. As the distance increases beyond this point, the illumination of the receiver decreases in approximately inverse proportion to the square of the distance.

Through the use of a large number of fiber optics fibers, the Fotonic sensor achieves the first claimed practical application of this principle. Although the principle is valid for even one pair of transmitting and receiving elements, the amount of returned light and slope of the resulting response curve is improved by the use of a large number of fibers.

The Fotonic fiber optics system permits, for the first time, the positioning of many pairs of elements in a very small space, giving the steep response curve necessary to provide extremely accurate displacement measurements.

Fiber Optics System

Remote illumination and viewing techniques employing fiber optics have been in use for several years, notably in medical and quality control applications. A number of firms, in this country and abroad, are marketing devices which use the phenomenon in one way or another. Such systems are in use in the process and information industries, in machine shops to illuminate specific work areas, in parts counting and inventory, in surgery and exploration, and in other diverse fields.

In the Fotonic sensor, the light-conducting properties of fiber optics permit positioning of the measuring com-

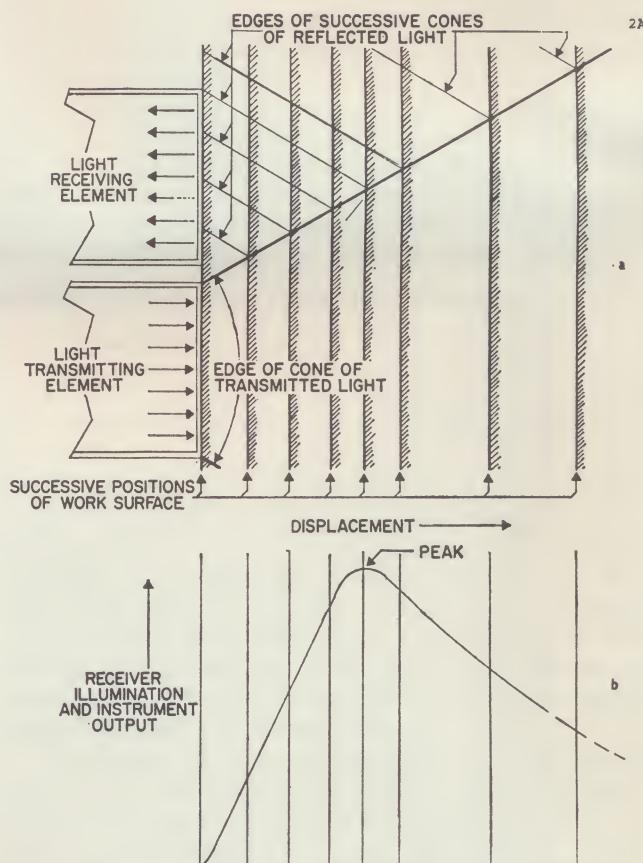


FIG. 1. PRINCIPLE of displacement measurement.

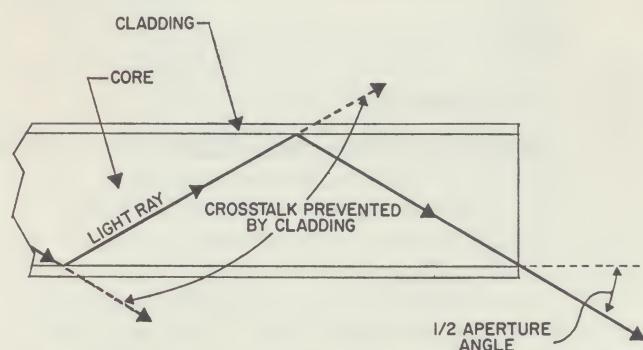


FIG. 2. LONGITUDINAL cross-section of glass fiber.

SENSOR

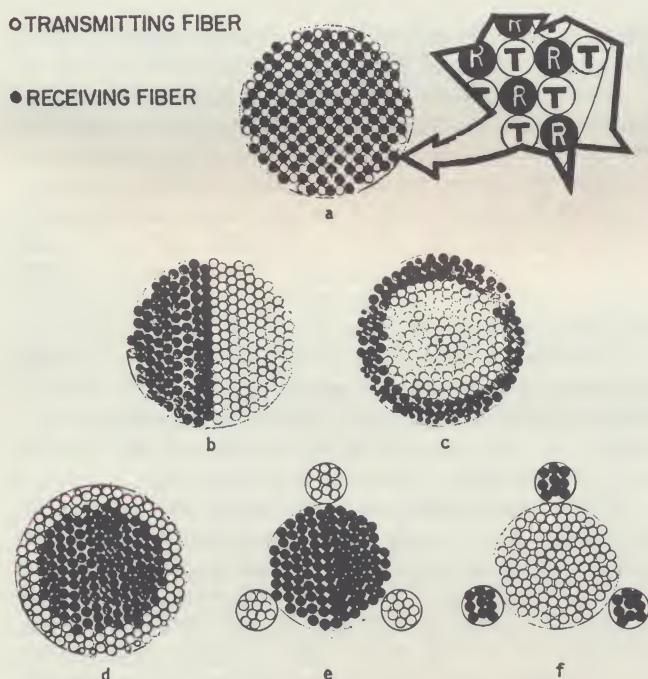


FIG. 3. VARIATIONS in fiber distribution.

ponents (light source and photocell) at a distance relatively remote from the measurement point. Also the physical flexibility permits measurements which would be impossible, because of space limitations or environmental conditions, if the optical path between measuring components and measuring point were rigid.

The sensitivity of a fiber optics measuring instrument is a function of the characteristics of the fiber bundle used. These characteristics can be carefully controlled, and include the quantity of fibers, their size and distribution, and the numerical aperture of the individual fibers (the angle at which light can enter or leave the end).

The probes used in the various Fotonic models employ high-quality fibers, each individually clad to prevent optical crosstalk. The core is flint glass with a refractive index of 1.62. The cladding—another type of glass—has a refractive index of 1.52. This difference in index causes total reflection of the light rays within the fiber core (Fig. 2) and prevents any of them from escaping and entering adjacent fibers.

This index difference also governs the maximum angle of internal reflection, thereby determining fiber aperture angle. In the standard Fotonic probe, 600 fibers, each 0.003 in. dia, are gathered in a cylindrical bundle. Near one end of the probe, the bundle is divided into two equal branches: one for light transmission, the other for reception. Synthetic or plastic fibers may also be used.

Distribution of fibers at the unbranched end of the bundle is a major factor controlling displacement range and slope sensitivity of the probe. For example, the optimum arrangement for the steepest response curve (and therefore the most sensitive response) involves surrounding each receiving fiber with four transmitting fibers (Fig. 3a). With this configuration, more and more receiving fibers are affected by the light which emanates from a single transmitting fiber as the distance between probe and work surface increases. Perfect realization of this configuration would imply careful deposition of alternate layers of transmitting and receiving fibers.

TABLE I. EFFECTS of varying fiber optics characteristics.

Characteristic	Probe No. 1	Probe No. 2	Probe No. 3	Probe No. 4
Probe Range	$\pm 0.0025''$	$\pm 0.020''$	$\pm 0.010''$	$\pm 0.080''$
Probe Outside Diameter	0.109"	0.109"	0.250"	0.250"
Fiber Size	0.003"	0.003"	0.008"	0.008"
Fiber Quantity	600	600	600	600
Fiber Distribution	random	hemispheric	random	hemispheric
Aperture Angle	60°	60°	60°	60°

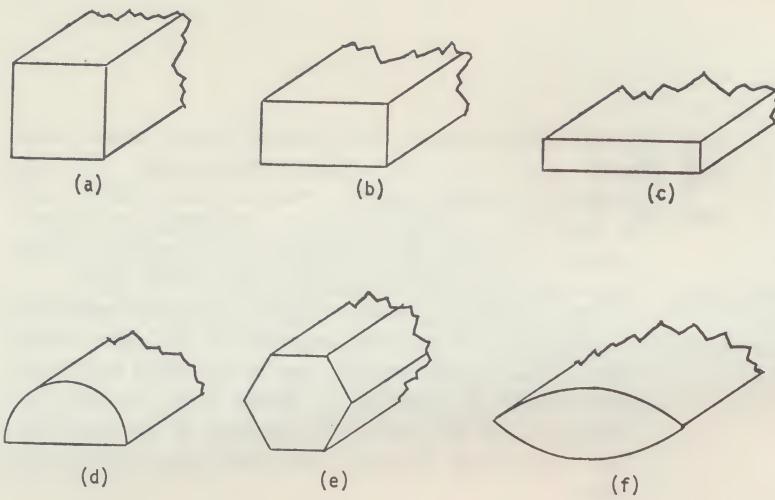


FIG. 4. VARIATIONS in geometry at end of probe.

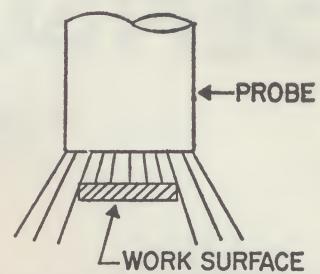


FIG. 5. EFFECT when work surface is smaller than probe.

The high expense associated with this procedure can be avoided through a well-controlled technique for randomly distributing fibers at the common end. Achieved within the constraints of manufacturing and assembly economy, this provides a response curve closely approximating the optimum. The quality assurance specification governing the technique requires that "no visible groupings of adjacent transmitting or receiving fibers can be seen." Conformance is easily checked by applying a light source, in turn, to each branch at the other end of the bundle.

Table 1 demonstrates the effects of varying one or more of the fiber bundle characteristics. It is immediately evident that the displacement range of a probe can be increased by a factor of eight merely by changing the fiber distribution from random to semi-circular or half-and-half—the semi-circular division of the transmitting and receiving fibers at the common end of the probe (Fig. 3b).

Additional distributions, over which the probe designer has complete control, are illustrated in Figs. 3c through 3f. The data in Table 1 for Probe No. 3 describe the changes in fiber size and bundle diameter necessary to achieve a displacement range of ± 0.010 in. The data for Probe No. 4 again demonstrate the range increase obtained when distribution is changed from random to hemispheric.

These four probes are just representative of the many which can be designed for various displacement ranges. A computer program has been evolved which permits rapid determination of fiber quantity, size, distribution, and numerical aperture necessary for any specific displacement range.

The Fotonic was developed by the Instruments Division of MTI as a self-calibrating unit for the highest possible resolution in the observation of minute displacement. For this reason a comparatively short-range probe (No. 1 in Table 1) was selected as standard, since it produces resolutions of 1 to 10 μ in. Exploratory work has been done with a number of other configurations, including Nos. 2, 3, and 4 in Table 1.

The amount of light that emerges from one end of an unbranched bundle will always be less than the amount directed into the other end. The loss during transmission is a function of the bundle length and end loss. For example, irrespective of size or quantity of

fibers in any bundle, light loss is approximately 50% for a 6-ft length and 80% for a 12-ft length.

Since the Fotonic must analyze a signal produced by passing light in two directions through a branched bundle, the light to be measured is only a small percentage of another small percentage of the total provided by the light source. For this reason, a fiber bundle sufficiently long for working purposes yet sufficiently short to ensure satisfactory light reception at the photocell, was selected. For the standard probe of 0.109 in. OD this optimum length is 3 ft.

The common end of the probe need not have circular geometry as has been suggested so far. If the surface to be studied is square, rectangular, semicircular, polygonal, oval, etc., the end of the probe can be made to conform exactly to this geometry. (Fig. 4.)

This is particularly important when one or both dimensions of the work surface are smaller than the probe. In this event (Fig. 5), some of the transmitted light will spill over the edge of the work surface and will not be reflected, reducing the effective area of the common end of the probe. The distance indicated by the instrument will thus be the average of the distance between the effective area of the probe and the work surface. To avoid similar errors when observing cylindrical surfaces, the probe used should be as small as practical and should have a rectangular end geometry oriented with the long axis of the rectangle parallel to the cylinder axis. This ensures that the work surface presented to the probe is as nearly flat as possible.

The smaller the bundle, the less light transmitted. When probes of smaller diameter are required because of the surface geometry to be studied, it is necessary to reduce probe length to less than the standard 3 ft to restore the light at the photocell to an adequate level. Accordingly, as probe diameters decrease from the normal 0.109 in. to 0.062 in., 0.030 in., or even smaller, the probe lengths are reduced from 36 in. to 18 in., 12 in., etc.

Design Characteristics

The basic measuring components are the light source and the photocell receiver. The former is a prefocused, incandescent-filament, 2.5-v bulb, with 10,000 hr life at that operating voltage. The bulb is normally driven at voltages from 1.0 to 1.7 to extend its life.

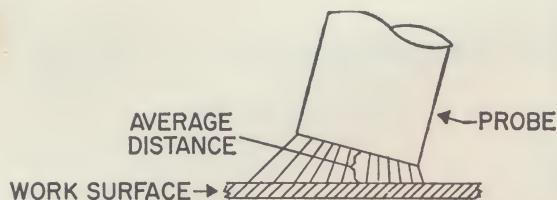


FIG. 6. EFFECT of probe misalignment.

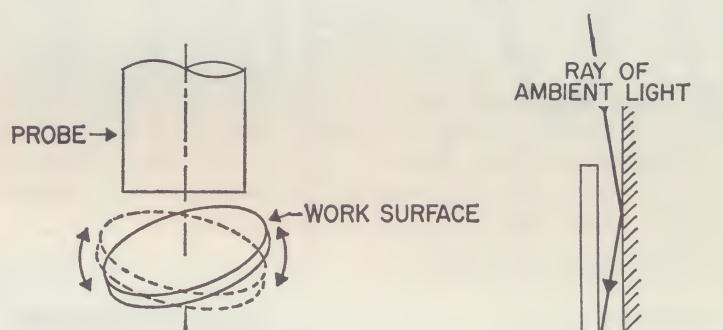


FIG. 7. EFFECT of work surface with eccentric motion.

The various Fotonic models employ different types of photocell receivers, depending on the instrument frequency response desired.

Models KD-38 and KD-45 use a planar photo diode which generates a current output dependent on the intensity of the light carried to it by the receiving branch. In conjunction with circuitry in the control unit, this cell provides a flat frequency response from DC to 100 kHz (Model KD-45) although there may be minor variations from cell to cell. The KD-47 uses a photocell and amplifier which produce a flat response to 2 MHz.

KD-36 is basically a static measuring instrument for observing extremely minute changes in displacement and periodic distance variations of low frequency. At its maximum gain setting, this model produces a 1-v DC output for every 10 μ in. of displacement. To provide the sensitivity necessary, these units employ a photo-conductive cell in which conductivity is proportional to incident light. Although the cell retains some sensitivity to 100 Hz, frequency response is limited in the Fotonic to the range DC to 20 Hz.

The 3-ft length of the standard probe may not always provide sufficient separation between the measuring point and the control unit. For this reason, light source and photocell of the Model KD-45 are located in a remote cartridge, connected to the control unit by multi-conductor cable. The probe extends directly from the cartridge, and any separation requirement in excess of 3 ft can be provided by the interconnecting cable. This also permits a single control unit to be used with a number of cartridge/probe combinations (e.g., if a probe of smaller or larger than standard diameter is required).

For analyzing the signal produced by the Fotonic, output terminals on the front panel enable connection of static or dynamic electrical recording or display devices (e.g., vacuum tube voltmeters, digital voltmeters, oscilloscopes, oscillographs, recorders, and counters). The DC resistance across these terminals is 1,000 ohms. A panel meter also on the front panel aids instrument setup.

Calibration can usually be accomplished in less than 30 sec with minimal experience and equipment. Since no physical forces are involved in the measurement, only a simple mechanical fixture is necessary to secure

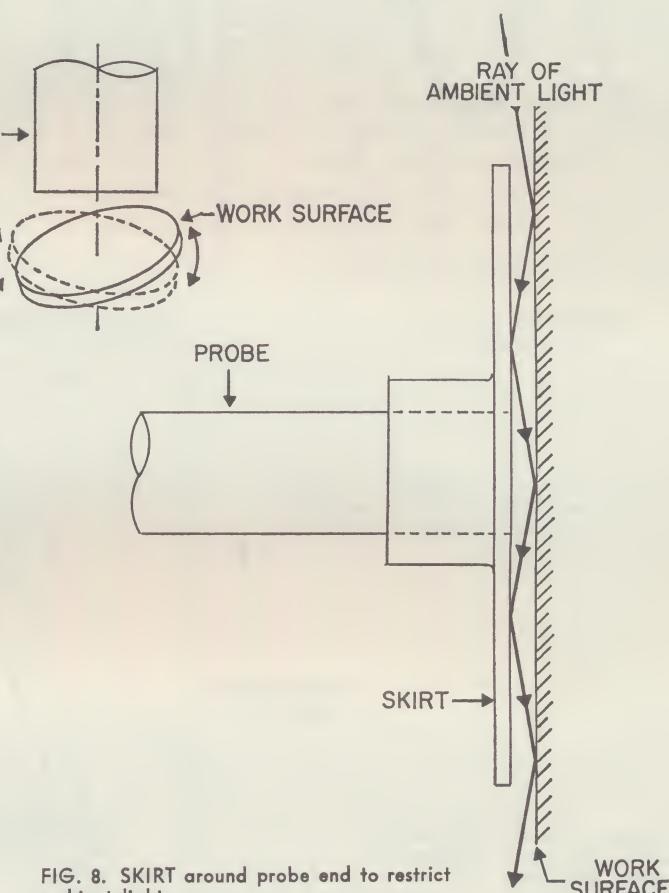


FIG. 8. SKIRT around probe end to restrict ambient light.

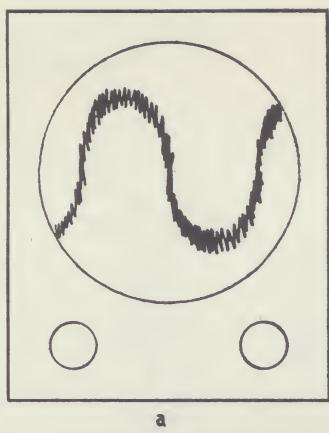
the probe near to the work surface. A voltmeter is connected so that peak output can be observed as the probe approaches the surface.

When this peak position has been identified, the light intensity control is adjusted until the voltmeter indicates 2-v DC. Reference to the calibration curve provided with each instrument enables correct positioning for a specific measurement. This procedure simultaneously accomplishes calibration of the instrument against the work surface.

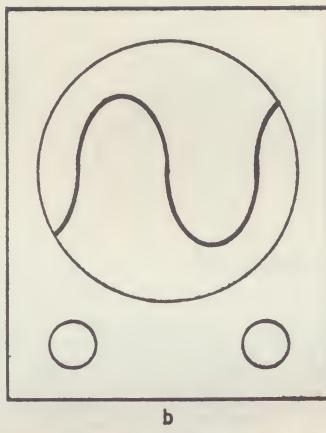
Care must be exercised that the common end of the probe is parallel to the work surface, or the average distance between probe end and the surface will be indicated (Fig. 6).

If the angle between probe end and surface becomes extreme, part of the transmitted light may be reflected at an angle too great to affect the receiving fibers, introducing additional errors into the reading. Moving the work surface in several simultaneous modes (Fig. 7) will also produce alignment errors and erroneous displacement readings, even though the initial probe positioning were correct.

Although the probe end must always be parallel to the surface being examined, there are many measurement situations in which the probe itself must approach the work surface at an angle. Within certain limitations, it is possible to introduce the necessary bends into the sheathing of the probe.



WAVEFORM WITHOUT FILTRATION



FILTERED WAVEFORM

FIG. 9. EFFECT of electronic filtration on instrument response.

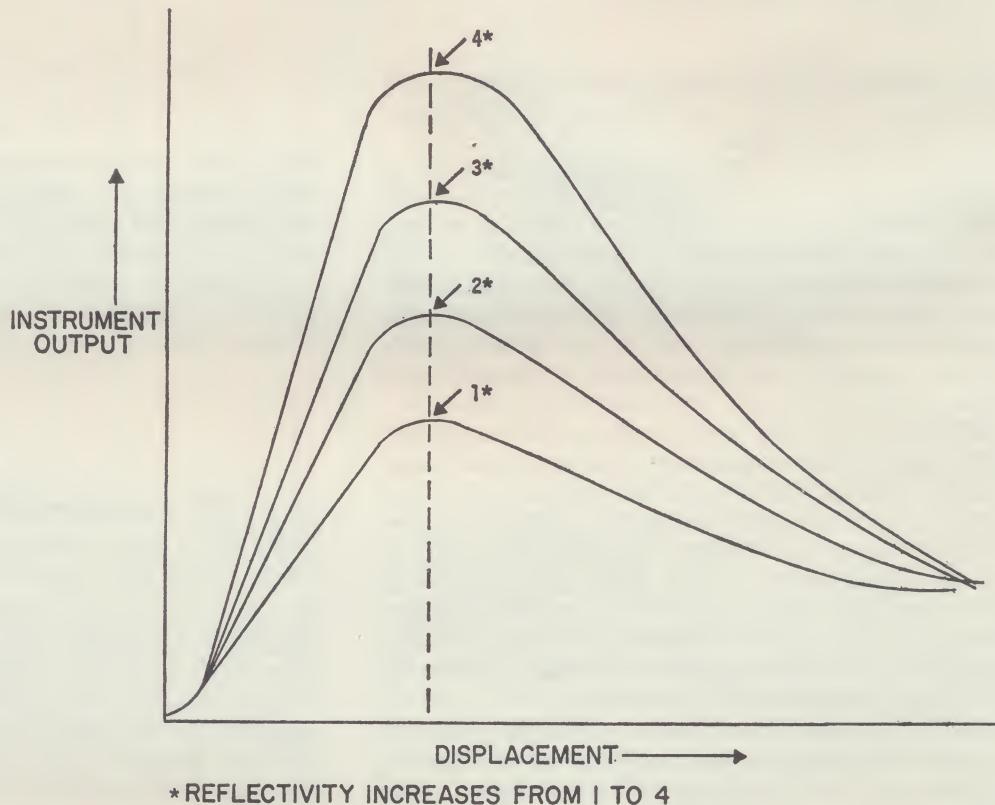


FIG. 10. VERTICAL shift of response peak with variation in surface reflectivity.

The standard probe will withstand a bend of $5/8$ in. radius; some of the smaller diameters have withstood smaller radii bends when they were carefully made. While probes are designed to provide a long service life under normal conditions of reasonable care, they will break if subjected to excessive abuse. Careful mounting and handling techniques are necessary. With the smaller probes in which there may be as few as 30 fibers in the bundle, the loss of a single fiber can cause a substantial loss in total instrument performance.

The photoconductive cell in Model KD-36 may be sensitive to ambient light in the test area. Such interference can be prevented with a small skirt around the end of the probe (Fig. 8), ensuring that all ambient light rays approach the probe end at an angle greater than the aperture angle of the fibers. An alternative solution is to provide an opaque shroud over both probe end and work surface at the point of measurement.

Measurements on surfaces which move perpendicular, as well as parallel, to the axis of the probe are

sometimes difficult to accomplish, due to response to variations in work surface reflectivity, which may become apparent under such conditions. This response is manifested as "noise" superimposed on the desired instrument indication. Automatic compensation methods for reflectivity variations are discussed below.

In the absence of automatic compensation, a cleaner signal can usually be obtained with a variable frequency electronic bandpass filter between the Fotonic and the readout device. Oscilloscope traces of instrument response with and without intermediate filtering are shown (Fig. 9). Minor adjustments of filter setting may be necessary to achieve maximum signal purity.

Response Curve Characteristics

The curve of instrument output *versus* work surface displacement (Fig. 1b) can be divided into three portions. The "front side" is the normal working region in which sensitive, linear output is obtained. The displacement range over which this portion of the curve is linear

(e.g., 0.010 in.) is considered the normal range of the associated probe.

The "back side" of the curve can also be used in measuring displacement, since output throughout this region is again a function of the distance between probe end and work surface. Because the back side is much less steep than the front side, the displacement range is greater, and the resolution poorer by over an order of magnitude. Since this portion of the curve is not truly linear, the accuracy of the instrument is a function of how much of the curve is employed.

Nevertheless, if these limitations are taken into consideration, the operation of the Fotonic on the back side

of the response curve provides a useful extension of its capabilities. For this reason, full-scale calibration, in terms of $\mu\text{in}/\text{mv}$, is performed on each unit, and the resulting data are furnished when the instrument is shipped, so that the user can employ either side of the response curve.

The third portion of the curve is the region adjacent to the peak which, as previously discussed, occurs at that displacement at which all the receiving fibers are illuminated by reflected light. The slope of the curve changes rapidly in this region, and output is no longer a linear function of displacement. At the peak itself, output is entirely a function of the reflectivity of the

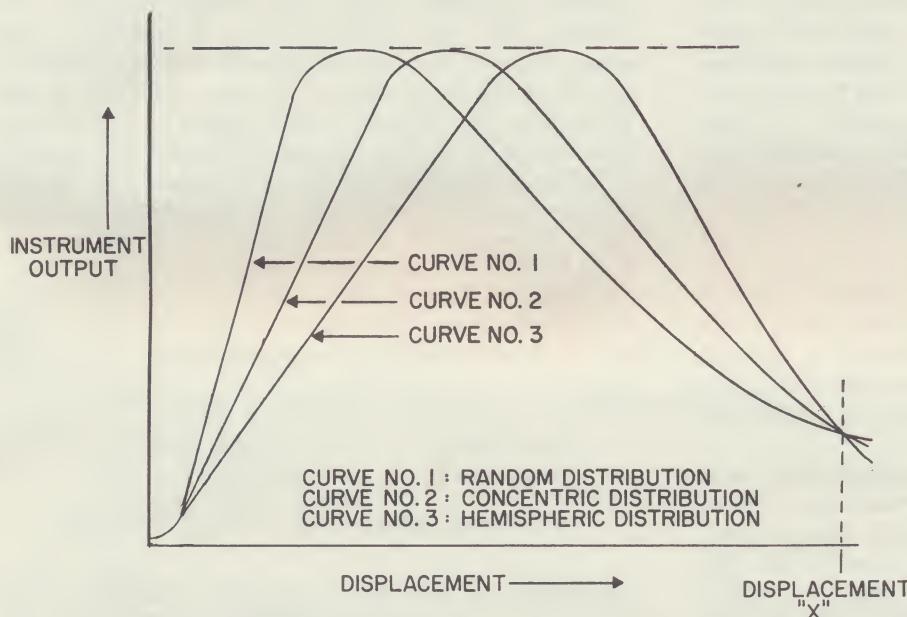


FIG. 11. EFFECT on response curve of variations in fiber distribution (size and quantity of fibers held constant).

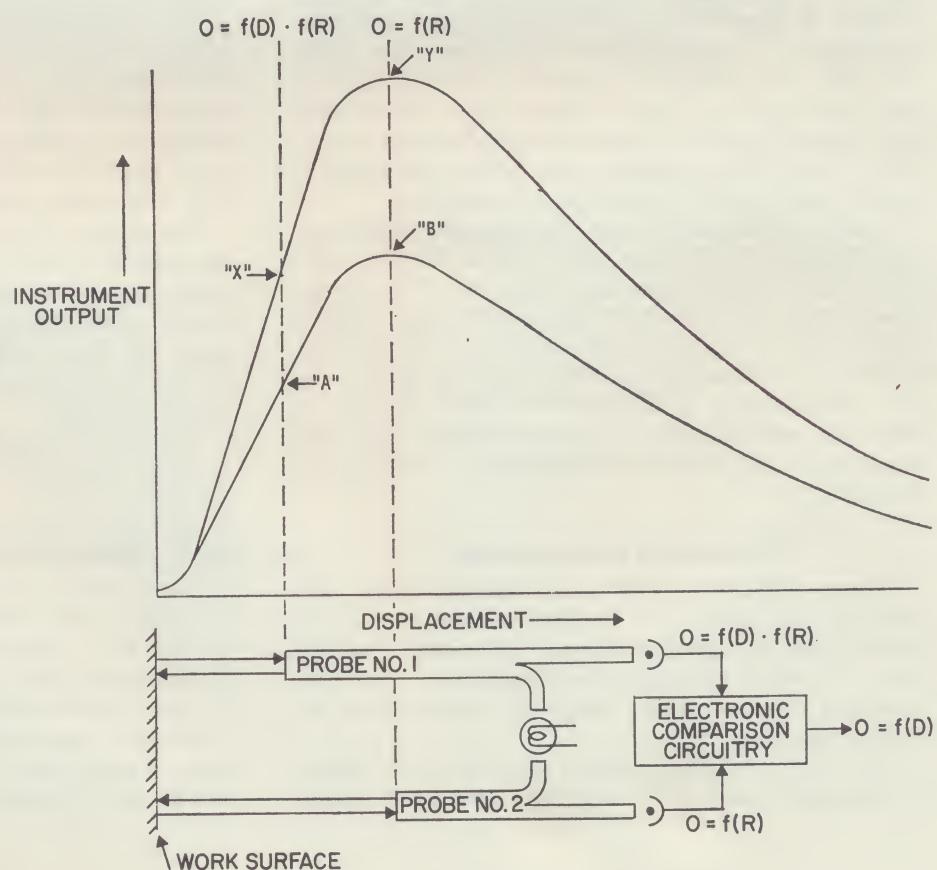


FIG. 12. A METHOD of achieving automatic reflectivity compensation.

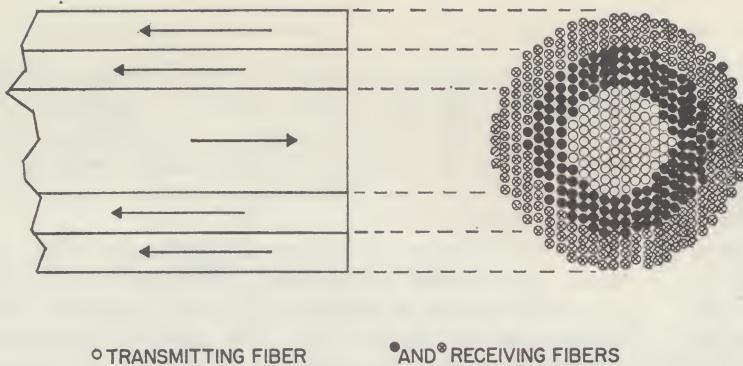


FIG. 13. SINGLE probe with triaxial fiber distribution for automatic reflectivity compensation.

surface being examined, and any change in output is the result only of a change in surface reflectivity.

This behavior of the response curve provides the Fotonic with an additional capability: high-speed, automated measurements of comparative surface reflection by the observation of processed parts with the probe set at the peak distance. For any given probe, the shape of the output *versus* displacement curve remains constant regardless of work surface reflectivity, and the curve will always attain its peak at the same distance.

With the intensity of the Fotonic set at a constant level, a probe which traverses a specimen characterized by many variations in reflectivity will produce a reaction to those variations, irrespective of the distance at which the probe is positioned. If the peak distance is selected, the peak of the response curve will actually shift along a vertical axis as the result of the existing surface discontinuities (Fig. 10).

Fig. 11 compares the response curves obtained with probes incorporating the same number and size of fibers but with different fiber distribution at the common end. Curve 1, approximately that of the standard probe with its random-fiber distribution, rises sharply to a rather close peak, then falls off very gradually with distance.

Curve 2 represents a probe employing concentric distribution of transmitting and receiving fibers (Fig. 3c). The front side is less steep than that of Curve 1 but covers a greater range of displacement. The region adjacent to its peak is of approximately the same width, but the back side is steeper, more linear, and covers a smaller range (and is therefore more sensitive).

Changes of the same nature but in greater degree are displayed by Curve 3, for a probe whose fibers are distributed in a semi-circular array (Fig. 3b). The steepening of the back side as the peak shifts to the right is a direct result of employing the same size and quantity of fibers in all three probes. As a result of these common denominators, and because a given number of fibers can conduct only a given amount of light, the output of the instrument at displacement *X* tends to be constant.

Reflectivity Compensation

Except at the very peak of the response curve, the output of the Fotonic is a function of both surface reflectivity and the distance between the surface and the probe. It would obviously be desirable to make displacement measurements completely independent of surface reflectivity.

One method of automatically achieving this utilizes the principle illustrated in Fig. 12. This figure shows

that, although the peak of the response curve shifts vertically with variations in surface reflectivity, the ratio between two points on the curve remains constant. For example, the ratio between points *X* and *Y* on the upper curve is the same as the ratio between points *A* and *B* on the lower curve. To take advantage of this ratio effect, two different probes, supplied by a common light source but feeding separate photocells, are mounted at different distances from the work surface. In Fig. 12, one has reached its peak while the other is still operating on the linear portion of the response curve. The output, *O*, of Probe 1 is a function of displacement, *f(D)*, and reflectivity, *f(R)*, while the output of Probe 2 is a function of reflectivity, *f(R)*, alone. These two outputs can be compared by electronic circuitry in the Fotonic as follows:

$$\begin{aligned} \text{from Probe 1:} \quad O &= f(D) \cdot f(R); \\ \text{from Probe 2:} \quad O &= f(R); \\ \text{compensated output:} \quad O_C &= \frac{f(D) \cdot f(R)}{f(R)} = f(D) \end{aligned}$$

thus producing an output independent of surface reflectivity. It is the electronic comparison of these two outputs at points *X* and *Y* that permits the accomplishment of linear and compensated measurements over the distance from point *A* to point *B*. To avoid the directional compensation that would result from the use of two independent probes, the "ratio effect" principle can be implemented by using a single probe employing triaxial fiber distribution geometry (Fig. 13).

The theory for this technique has been proved by Mechanical Technology Inc. (MTI), from both electronic and optical viewpoints. Prototype equipment has been in trial operation for some time, and test equipment has been built for use on customer-sponsored hardware performance studies conducted by MTI's Research Division.

The Fotonic Sensor, which is essentially a zero-force-exerting instrument is in varied use measuring such previously difficult or impossible to measure variables as ultrasonic welding head motion; clearance of operating gas turbine blades; minute high frequency blood pressure changes due to heart valve action; width and/or thickness of continuous process sheet or stock, such as thickness measurement of vacuum deposited metal on transparent film; level sensing of viscous, corrosive or otherwise difficult to sense liquids, etc.

It can be used to detect displacement, vibration, motion, or dimension to fractional microinches at frequencies from dc to several megacycles.

KD-38 fotonic sensor



features

NON-CONTACT MEASUREMENT

Eliminates possibility of distorting materials being tested.

SELF-CALIBRATING

FREQUENCY RESPONSE TO 40 KC

CAN TEST NON-CONDUCTIVE MATERIALS

RESOLUTION — 10 MICROINCHES

PROBE — UNAFFECTED BY EXTERNAL FIELDS

Operates in wide range of environment.

VERSATILE, COMPACT, EASY TO USE

ECONOMICALLY PRICED

applications:

- Detection of micro circuit chips
- Cam or lever mechanical indexing
- Automation control
- Ultrasonic crystal motion
- Tachometry
- Vibration and Displacement Sensing
- and ?

The **KD-38** is the smallest and least expensive member of the growing family of MTI non-contact optical proximity detectors. The hand-sized **KD-38** can detect surface finish changes and flaws and measure displacement or motion at frequencies from DC to 40 KC. It is capable of measuring to 10 millionths of an inch, by the application of a unique fiber optics principle.

The .109" diameter sensing probe contains 600 randomly distributed strands of glass fiber optics encased in a plastic covered flexible steel monocoil jacket. Half of the fibers transmit light which, after being reflected from the observed object, is captured by the remaining 300 fibers and translated into an analog output signal. The static signals can be read directly from the integral meter or applied to external equipment such as a digital voltmeter via the output jack.

Dynamic signals (vibration) can be read by using the **KD-38** output with an oscilloscope.



968 ALBANY-SHAKER ROAD, LATHAM, N.Y. 12110

specifications

Typical Linear Sensing Range

- A. to within ± 50 microinches
- B. to within ± 100 microinches

2 mils

5 mils

Total Typical Range

- A. Front Side Curve
- B. Back Side Curve

20 mils

180 mils

Output Impedance

4k Ohms*

Output Sensitivity

10 microinches/millivolt

Output Frequency Response

Flat from DC to 15 KC;
3 DB down at 40 KC

Output Level

1 volt DC at full scale
meter reflection

Operating Temperature Range of Probe Tip

Cryogenic to 300° F

Compensated Operating Temperature Range of Instrument

60° F to 95° F

Uncompensated Operating Temperature Range of Instrument

10° F to 150° F

Light Source Life Expectancy

10,000 hours average

Stability (drift)

Sensitivity change—less than $\pm 5\%$
over a temperature range of
60°-95° F and line voltage
variations of 110-130 VAC.

1 inch

Probe Minimum Bend Radius

Probe Dimensions

36" long with 3" long stainless
steel end tip. Tip O.D. .109".

Weston taut band

Readout Meter

Approximately 3 watts at
110-135 volts, 60 cycles

Power Consumption

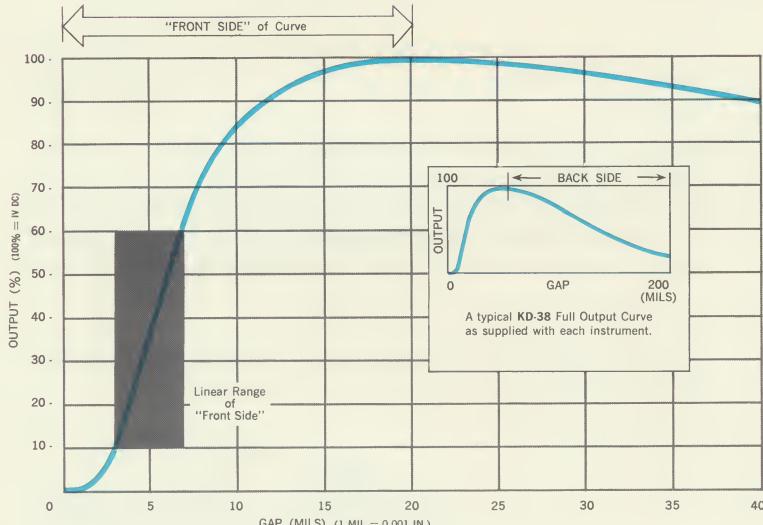
2 pounds, 6 ounces

Weight

Length—6½ inches,
Height—4 inches,
Width—3¾ inches

Size

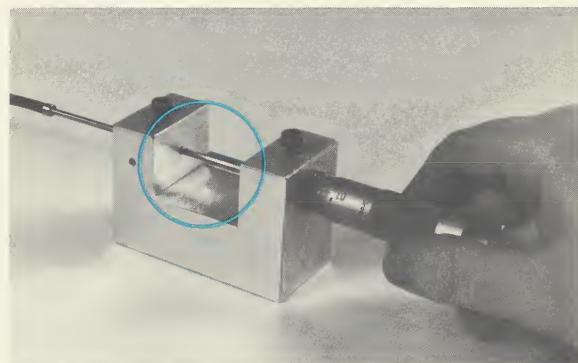
*Temperature compensation affected by low load resistance Readout device—
Recommended minimum—50K Ohm Load.



The normal working region (shaded area) denotes the "Front Side" of the KD-38 output/gap curve. Here the most sensitive linear output is obtained. Once the surface Compensator Knob has been adjusted to obtain output at peak of curve, the KD-38 is calibrated for the specific surface being observed.

Shown below is a typical test situation to illustrate the KD-38's adaptability. Mic block mounted probe is brought into contact with Mic head and gap widened to achieve response curve shown at left.

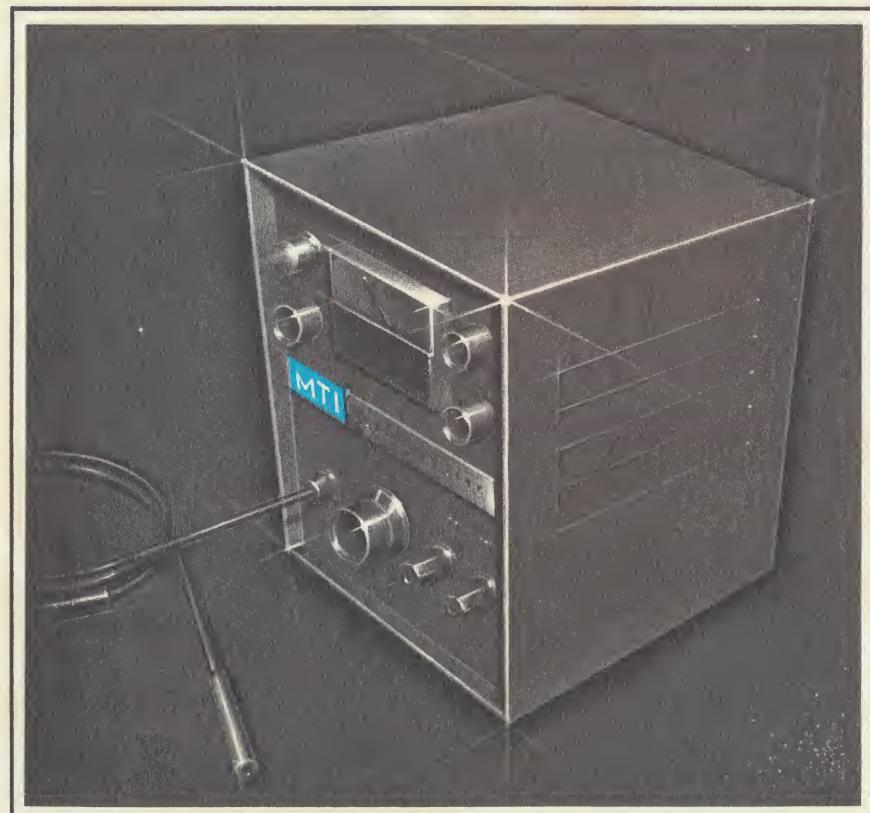
MTI offers many accessories to extend the scope of the KD-38 Fotonics Sensor in line with your particular needs. Details furnished upon request.



MTI

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TECHNOLOGY
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FOTONIC SENSOR OPTICAL PROXIMITY DETECTOR



A new concept for measuring displacement and motion . . . for determining surface finish and color . . . for process inspection and control.

WHAT IS A FOTONIC SENSOR?

The Fotonic Sensor is a non-contacting instrument which measures linear distance, displacement or motion by means of light rays. Such movement causes variations in the amount of light transmitted through a fiber optics probe and reflected by the work surface. This reflected light is transmitted back through the fiber optics probe to a photo receiver, whose output is indicated by a meter or displayed on the greatly expanded scale of an oscilloscope. The system is characterized by microinch sensitivity and high accuracy at frequencies from DC into the megacycle region.

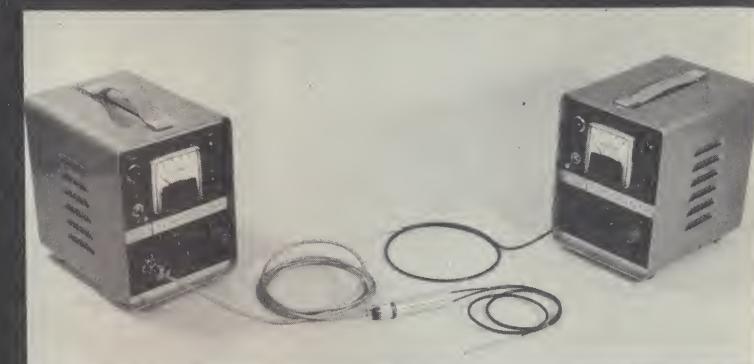
Combined with various transducer elements, the Fotonic Sensor and its associated line of detectors has found wide application in laboratory, shop, production and field instrumentation for measuring, monitoring or controlling vibration, shock, acceleration, pressure and temperature, as well as speed, thickness and flow. The versatility of application also includes surface finish comparison, color measurement, high speed counting and numerous types of gaging operations.

For original equipment market applications, special sensing heads permit greater latitude in the design of measurement, inspection or control elements, with the added advantages of small size, lack of complexity and low cost. The electrical output can be easily integrated into existing electronic display and control systems.

In the area of automation machinery, Fotonic Sensor detectors have important applications in the functions of inspection, gaging, testing and controlling. Four advantages are of particular interest: high reliability under normal factory environment, instantaneous scanning or response without the requirement of stop-start motions, non-contacting operation from a distance, and adaptability of electrical output to computerized control.

WHAT ARE THE ADVANTAGES?

1. High sensitivity, permitting motion or displacement measurement in millionths of an inch.
2. Non-contacting operation, neither adding weight nor absorbing power from the observed object.
3. High frequency response from DC to two megacycles, more than 100 times better than other available equipment.
4. Linear output with distance over the operating range.
5. Application to either metallic or non-metallic surfaces.
6. Small size probe diameter, down to 30 mils.
7. Sensing element is not subject to magnetic or electrostatic disturbances, nor does it introduce such disturbances in the workpiece.
8. Electrical grounding or insulation from ground of the probe or surface to be measured is not necessary.
9. Special probes for extreme environments from cryogenic temperatures to 1000 F and for high vacuum operation are available.
10. Reflection compensation units eliminate the need for recalibration for different surfaces and also permit operation on rotating or moving surfaces.
11. The instrument is small in size, light in weight, quickly adaptable to a variety of applications, and easily calibrated.
12. In addition to outstanding technical advantages, Fotonic Sensor applications are sufficiently economical to justify replacement of existing systems such as dial indicators, electronic gaging heads, reed comparators, strain gage instruments, air gages, and capacitance and inductive systems.



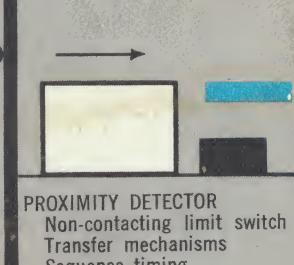
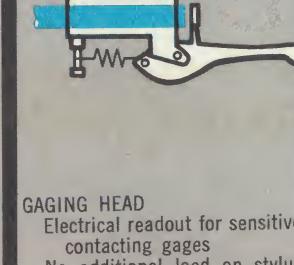
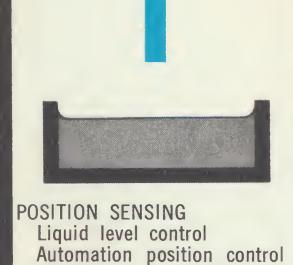
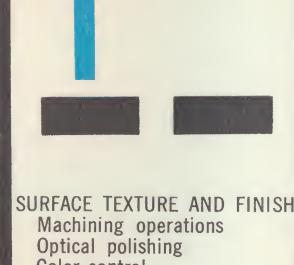
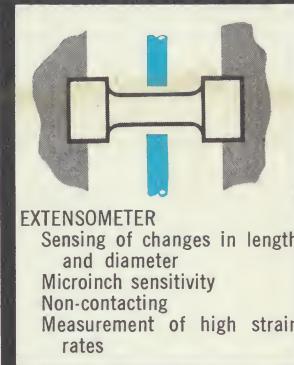
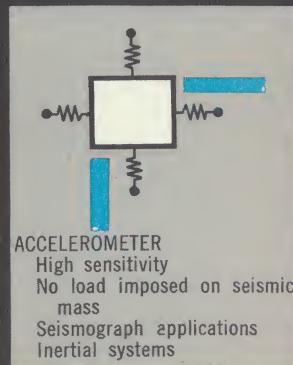
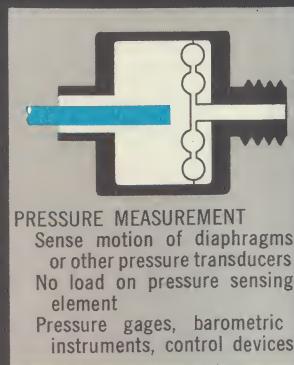
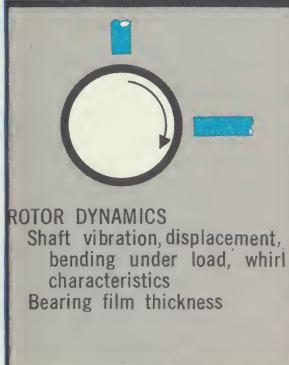
KD-45 Fotonic Sensor with detachable sensing cartridge (left) with electrical cable connection to control unit for remote location of cartridge and probe, and standard KD-35 with integral fiber optics probe (right).



KD-35 measurement of high frequency ultrasonic vibration of a "squeeze film" gas thrust bearing.



KD-45 applied to monitoring high speed shaft dynamic operating characteristics of vibration, displacement, and runout.

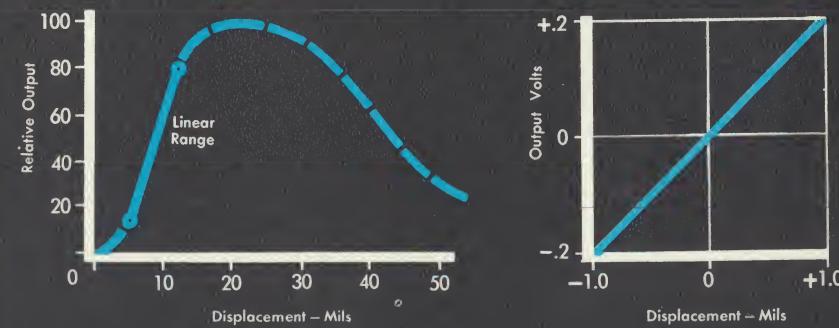


As the gap opens between the probe and the work there is a rapid increase in signal level with distance, reaching a peak at which the instrument becomes insensitive to changes in gap. Beyond the peak the signal becomes approximately inversely proportional to the square of the distance between the probe and the work.

The extremely sensitive and linear rise in the initial part of the response curve permits high accuracy, microinch displacement measurements. Operating ranges of one-quarter inch have been achieved, and ranges of the order of one inch are obtainable. The use of the inverse square portion of the curve permits a wider range of measurement at greater distances where sensitivity, linearity, and accuracy requirements are lower.

The peak portion of the curve can be employed when the instrument is used to detect variations in surface reflectivity due to surface finish or color changes, or when the instrument is used as a proximity detector to detect the presence of an object as a tachometer, for example. Reflectivity compensated probes, which utilize both the peak and linear portions of the response curve, automatically correct for variations in surface characteristics without the need for recalibration, leaving the system sensitive to distance changes only.

RESPONSE CURVES



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THIS IS MTI

The Fotonic Sensor and its associated line of detectors and controls are products of MTI's Instrument Products Division. Other Division products include electric capacitance probes for the non-contacting measurement of motion and displacement and the Micro-Dyne, which utilizes the capacitance probes in the dynamic analysis of the operating characteristics of rotating machinery.

The Company's unique competence in translating the current state of advanced technology directly into prototypes and proprietary products has found wide customer application for both government agencies and American industry. The technical staff of more than fifty scientists and engineers plus their skilled technicians have attained international recognition in the fields of gear technology, rotor dynamics, gas bearings, and the design and manufacture of automatic machinery. Other areas of technological leadership include bearings and lubricants, compressors, mechanical transmissions, turbines and turbomachinery components, as well as gages, instruments, instrumentation systems and control systems.

In addition to its extensive R & D work, MTI has excellent design and manufacturing competence. All of these capabilities can be focused on custom-tailored instrument engineering application programs for special laboratory instrumentation, machines for automation, automatic machinery, quality control inspection, and process measurements and control.

Address inquiries to:

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Instrument Products Division
Mechanical Technology Incorporated
968 Albany-Shaker Road
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Telephone: 518-785-0922

AREA CODE 518
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EVERETT E. BOYD
ASSISTANT SALES MANAGER

MECHANICAL TECHNOLOGY INCORPORATED
LATHAM, NEW YORK



968 Albany-Shaker Road-Latham, N.Y. 12110-Phone (518)785-0922

FOTONIC SENSOR PRICE LIST

Model No.	Integral Probe	Probe Tip Diameter (Inches)	Fiber Bundle O.D. (Inches)	Fiber ** Distribution	Approx. Number Of Fibers	Probe Length (Inches)	Linear $\pm 5\%$ Displmt. Range (Mils)	Maximum Sensitivity Microinch/mv	Frequency Response	Price List
A. KD-36	Yes	.109	.075	R	600	36	2	.1	DC-20 CPS	\$ 975
KD-38	Yes	.109	.075	R	600	36	5	10	DC-40 KC	259
KD-45	No	- - - - -	- - - - - (See Note 1 Below)	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	DC-100 KC	805
KD-47	No	.109	.075	R	600	36	6	4	DC-2 MC	1,090

NOTE 1: Consult lists "B" and "C" to select appropriate cartridge and probe for use with KD-45. Price of selected cartridge and probe must be added to price of basic sensor.

B. PROBES FOR USE WITH KD-45 FOTONIC SENSOR AND APPROPRIATE CARTRIDGE (All probes shown use glass fibers. Probes with synthetic fiber optics available on special order at \$10 less per probe. Fiber diameter nominal 3 mils for all listed probes.)

Model No.	Probe Tip Diameter (Inches)	Fiber Bundle O.D. (Inches)	Fiber ** Distribution	Approx. Number Of Fibers	Probe Length (Inches)	Linear $\pm 5\%$ Displmt. Range (Mils) (Typical)	Sensitivity Microinch/mv (Typical)	Price List
KD-P	.032*	.019	R	25	12	4	3	\$ 90
KD-P	.042	.027	R	100	18	4	3	80
KD-P	.065	.047	R	300	18	4	4	90
KD-P	.065	.047	rl	300	18	4	4	110
KD-P	.109	.075	R	600	36	6	4	50
KD-P	.109	.075	rl	600	36	50	30	100
KD-P	.285	.245	R	2000	36	20	15	150
KD-P	.285	.245	H	2000	36	125	100	200
KD-P	.285	.245	CTI	2000	36	125	75	225
KD-P	.285	.245	CTO	2000	36	50	40	225

* Recommended for special application only - consult factory.

** Fiber distribution key: R - Random
H - Semicircular distribution (Half & Half) at probe end
CTI - Concentric fiber orientation at probe end; transmit fibers inside
CTO - Concentric fiber orientation at probe end; transmit fibers outside

C. CARTRIDGES FOR USE WITH KD-45 AND PROBES LISTED ABOVE (Cartridges available for \$10 less/unit if calibration not required.)

Model No.	P/N		
KD-C	1XS	- extra sensitive for use with 32 mil probes (recommended for special application only)	\$ 135
KD-C	2S	- sensitive for use with 42 and 65 mil probes	115
KD-C	3R	- regular for use with 109 mil probes	100
KD-C	4SL	- special length for use with 285 mil probes	130

NOTE: Frequency response curve supplied only when instrument, cartridge, and probe purchased as a unit.

CORRESPONDENCE WITH THE FACTORY IS INVITED FOR SPECIAL APPLICATION OR SPECIAL PRICING IN QUANTITIES OF OVER 10 UNITS.

PRICES SUBJECT TO CHANGE WITHOUT NOTICE

PRICE LIST - 02-900 (11/66)

Terms: Net 15 Days

F.O.B.: Latham, New York

(continued)

Fotonic Sensor Price List
(continued)

D. ACCESSORIES FOR USE WITH FOTONIC SENSOR

Model No.

KD-F-2	NOISE FILTER	- fixed frequency 10 KC low pass (LC network), with offset, for use with all Fotonic Sensors.	\$ 60
KD-FO-1	NOISE FILTER	- noise filter, four fixed frequencies, (RC network) with offset for use with all Fotonic Sensors.	125
KD-FT-1	FOCI TRONIC	- light focus head for use with KD-45 and KD-47 only. Use of Foci Tronic must be specified when ordering either of these units. The Foci Tronic head allows displacement measurements over approximately 100 mils at sensitivity of approximately 60 microinches/millivolt while standing off from measured object approximately 1 1/8".	225
KD-CL-5	STANDARD FIVE FEET CARTRIDGE LEAD	- for use with KD-45 (i.e., 5' lead between Fotonic Sensor and cartridge). This item is included in base price of the KD-45.	9
KD-SP	SHADOW PROBES	- a two element light - interruption sensing system for width measurement or edge sensing. For use with KD-45 (on special order with KD-36) contact factory for engineering data and price.	250
KD-CC	CARRYING CASE	- for use with KD-36, 45, and 47	25
KD-MB	MIC BLOCK	- calibrating fixture for Fotonic Sensors. Calibrates in 0.001 increments.	50
KD-CH	CALIBRATING HEAD	- precision calibrating fixture for use with all non-contact sensing equipment. 0.0001 increments.	475
KD-TP	PHONE PLUG	- for use with KD-38; supplied with 5' shielded lead. Twin banana plug other end.	3